AR-009-401

DSTO-TR-0254

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Electrostatic and General Hazards Associated with Cleaning Army Fabric Bulk Fuel Tanks (TFCs)

Gunars Bajinskis, Horace Billon and Jim Quinn

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Gunars Bajinskis, Horace Billon and Jim Quinn

Weapons Systems Division
Aeronautical and Maritime Research Laboratory

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ABSTRACT

Assistance has been sought to assess the safety from electrostatic hazards of personnel cleaning the 45,000 L tank fabric collapsible (TFC) that is used by the Australian Army for fuel storage. Concerns centre on the level of electrostatic charge that may be generated on personnel while wearing protective suits and working inside the TFCs. If inappropriate attire is worn the energy of an electrostatic discharge from personnel can exceed the ignition energy of the most sensitive concentration fuel air mixture. Electrostatic tests were carried out on suits supplied and several conclusions regarding safe working conditions are listed. Although not directly related to electrostatics, other occupational health and safety aspects are raised in the report.

RELEASE LIMITATION

Approved for public release

DEPARTMENT OF DEFENCE

DEFENCE SCIENCE AND TECHNOLOGY ORGANISATION

Published by

DSTO Aeronautical and Maritime Research Laboratory
PO Box 4331
Melbourne Victoria 3001

Telephone: (03) 9626 8111
Fax: (03) 9626 8999

AR No. 009-401
November 1995

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Executive Summary

The Australian Army uses a 45,000 litre tank fabric collapsible (TFC) for fuel storage. There is a requirement that personnel be provided with protection against fuel contact when cleaning TFCs. Three types of protective suit have been tested. These are a Tyvek suit, a suit with an outer Saranex layer and a suit made of Breathalon.

Although this paper primarily evaluated electrostatic hazards associated with the suits, it also addresses other health and safety issues. These additional hazards are caused by fuel contacting unprotected skin and also by the effects of heat on personnel wearing the suits.

The TFCs are inflated to a height of about 1.8 m by an air blower. Personnel entering the TFC should be provided with air from an external supply via an airline. Personnel enter the TFC through a 400 mm wide access hole and they wear a harness and cable if rescue from the TFC should become necessary.

We noted that the Tyvek suit provided poor protection against fuel ingress and also wore out quickly. The Saranex suit provided good protection against fuel ingress.

When brown GP boots were worn by personnel the energy was below the minimum ignition energy (MIE) for hydrocarbon fuels which is 250 μJ. With insulating footwear it was found that the MIE could be exceeded by a factor of two. Energies similar to the MIE also occurred when the subject stepped on rags under conditions of low humidity. Breathalon suits produced higher peak potentials than Saranex suits under the same charging conditions.

Short potential decay times occurred when brown GP boots were worn while the decay times became unacceptably long when insulating footwear was worn. In all tests personnel wore selected garments and stood either on the TFC surface or on the floor.

Because of the fuels used it is necessary that skin contact be avoided. Although the Saranex and Breathalon suits might prevent skin contact they also encapsulate the wearer. Encapsulation under warm weather conditions can lead to a number of physiological hazards. In addition, the dimensions of the TFC access hole are below the value required by AS 2865-1986.

According to the manufacturer neither the Tyvek nor the Saranex suits are flame resistant and they should not be used in potentially flammable or explosive environments.

We have been informed that US and UK armed forces personnel are not required to enter similar fuel tanks for cleaning purposes.

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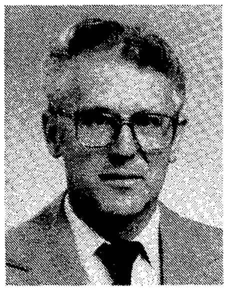
Gunars Bajinskis

Weapons Systems Division



Gunars Bajinskis joined AMRL in 1961 and was responsible for electrical evaluation of components and materials in the Type Approval Section. In 1967 he was requested to set up an electrostatics investigations unit to serve Defence and industry. Since then his work has covered a wide range of electrostatic topics in manufacturing, clothing, explosives safety, munitions handling and related accident investigations. He has also investigated sealant problems in the fuel tanks of F-111 aircraft and played a major part in the local development and manufacture of new high power HF antennas for the Navy. His current work as Senior Technical Officer involves electrostatic consultancy to the Services and to Australian Defence Industries.

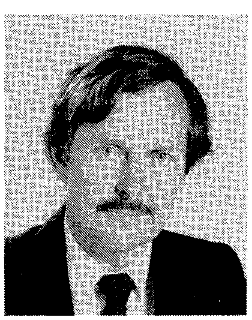
Horace Billon

Weapons Systems Division

Horace Billon graduated from Royal Melbourne Institute of Technology with a BSc in Applied Physics. He also has a Graduate Diploma in Mathematical Methods from Royal Melbourne Institute of Technology. After working in the RAAF Quality Assurance Laboratories at Highett he joined AMRL in 1986. He works in the Weapons Systems Division, and his primary areas of interest are explosives rheology and electrostatics.

Jim Quinn

Weapons Systems Division



Jim Quinn obtained his BAppSc(Applied Physics) at the Royal Melbourne Institute of Technology in 1973 and is a Member of the Australian Institute of Physics. He joined the Materials Research Laboratory (now AMRL) in 1969 and has been involved in X-ray crystallography, dimensional metrology, X-radiography, image analysis, pattern recognition and simulation methods for electromagnetic pulse effects on electronic systems. In the weapons systems area he has worked on the problems associated with the introduction of software controlled technology into the safety and arming units of fuzes for explosives ordnance. More recently he has assumed responsibility for protecting defence personnel and materiel from electrostatic discharge, lightning and related effects.

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1. Background

The Australian Army uses a 45,000 litre tank fabric collapsible (TFC) to store fuel for distribution in the field. The TFCs are made from reinforced neoprene and while empty they can be collapsed and folded into a relatively small space for storage and transport. At a field fuel depot the TFC is laid out in a bund and connected with a pipe system for filling and distributing fuels as required (Fig. 1). The fuels stored are diesel, avgas, avtur and petrol.

Present practice is to periodically clean the inside of the TFCs prior to changing fuel or preparing for transport and storage. The cleaning procedure [1] requires personnel to enter the TFCs after excess fuel has been removed (Fig. 2). The procedure cites compliance with the necessary safety regulations and standards of hygiene of the Australian Defence Organisation [2]. Precautions taken require the person entering a TFC to utilise a breathing air supply, in this case via a hose connection to air bottles adjacent to the tank. The present task arises from a HQ 1 Div. Army Research Request to provide advice on a proposed requirement to include a barrier against fuel contacting the skin of personnel inside the TFC.

A disposable suit with an outer Saranex layer impervious to the fuels is being trialed. This suit is current RAAF issue (stock number 8415-66-116-1768) and is in the form of an overall with elastic cuffs and sleeves. The suit includes a hood to protect the head. A second suit manufactured from Tyvek was also tested, although this has inadequate mechanical and fluid barrier qualities. A third suit made from Breathalon, a material impervious to fuel and claimed to be able to transpire moisture to its external surface, was also tested in the laboratory.

Electrostatic tests were carried out on the Saranex and Tyvek suits at the Royal Australian Army Ordnance Centre (RAAOC) at Bandiana in Victoria. Activities at this site are limited to training and so cleaning operations were not examined. Cleaning operations are carried out almost exclusively at 2nd Field Logistics Battalion located in Townsville, Queensland. Further tests were carried out at Aeronautical and Maritime Research Laboratory's Maribyrnong electrostatic testing facility.

The tests are primarily aimed at evaluating electrostatic hazards associated with the proposed protective suits. This paper characterises the electrostatic properties of the three suits and outlines the conditions required for electrostatic safety. The nature of the task involves a number of other occupational health and safety issues which are also discussed. Relevant regulations with respect to working in a confined space are referenced.

Due to the possible deleterious health effects personnel are required to avoid fuels contacting the skin. Navy regulations [3] state: "When handling fuels, personnel must wear appropriate protective clothing. If clothing becomes soaked, it should be removed as quickly as possible. The skin should be washed with soap and water". Protective suits can provide an effective barrier against fuel contact by encapsulating the wearer. However this introduces a new hazard since encapsulation inhibits the ability of the wearer to expel body heat.

2. Overview of TFC Cleaning Activities

The procedure for entering and exiting the TFC was observed at RAAOC. Measurements on the equipment and personnel were arranged to coincide with training for Petroleum, Oil and Lubricants (POL) operators. The training procedures did not involve cleaning operations but did include entry and rescue exercises.

The TFCs are inflated with air from an air blower through a pipe connected at one end. The TFC inflates to a height of approximately 1.8 m at the centre tapering to ground level at the edges. Air passes through the TFC and is emitted through an access hole at the other end. The cover plate for the access hole is rested on the metal frame of the access hole to restrict the air flow.

Personnel entering a TFC for cleaning operations are reported to have an air supply provided to a mask via a hose leading to compressed air bottles external to the TFC. We were informed that as an exemption for the training exercise, breathing masks with filter canisters were used instead of the air line.

A safety harness is worn by personnel and this is attached at the back to a cable that extends outside through the access hole. The safety harness and cable are used for rescue in case personnel in the TFC become incapacitated.

Entry to the TFC during our visit was limited to one person who stepped through the metal-framed access hole. The maximum width of the access hole is 400 mm, which results in a tight fit around the body of larger personnel. Assistance is rendered to the person entering by two attendants who guide the person and manipulate the top of the TFC and the access hole frame over the upper body and head.

Exiting the TFC requires the person to first place both arms through the access hole and then stand up to full height. Assistance is generally required at this stage from the attendants. Exiting the TFC with arms placed by the sides is virtually impossible. In simulated rescue exercises the rescue cable is looped around the wrists so that they are the first part of the anatomy to emerge through the access hole.

During the exercise the Saranex garment provided a good barrier to the small amount of fluid in the TFC. The Tyvek garment was inadequate; it absorbed fluid that contacted it and wore through with only moderate abrading. In fact, the manufacturer's report recommends that Tyvek garments are not to be used as protection against liquid chemicals [4]. A third potentially suitable garment made from Breathalon was used in later tests but was not available for the RAAOC tests.

3. Experimental

3.1 Apparatus

Potential was measured by means of a Rothschild R-1020 electrostatic voltmeter. Resistance was measured by a Radiometer IM6 or by a Monroe Electronics ME278 Picoammeter. Capacitance measurements were conducted by means of a General Radio Company Type 1650-A impedance bridge. A stopwatch was used for the potential decay tests. Temperature and humidity were measured with a Vaisala HM 34 humidity and temperature meter.

3.2 Materials

Two 45,000 litre TFCs used in the measurements were manufactured in fabric and neoprene by Marsden, Wolverhampton, UK.

Tests carried out at RAAOC were performed on personnel in their standard attire. Army personnel wore disruptive pattern combat uniforms (DPCU) and brown general purpose (GP) boots. AMRL staff wore civilian clothes and shoes throughout tests. A Tyvek protective suit and a Saranex suit were tested on Army personnel during scheduled training exercises with a TFC.

A series of tests was conducted at the AMRL Maribyrnong site. These included tests in the laboratory and outdoors using a second TFC. Clothing worn during the AMRL tests utilised sample DPCU uniforms that are kept for experimental purposes. For this series of tests sample DPCU trousers, shirt and GP boots were used. As well as Tyvek and Saranex protective suits a Breathalon suit was also tested. To simulate footwear with insulating soles a pair of Puma Hurricane sports shoes was used. The electrostatic effects of tools used in the cleaning operation were measured at AMRL. The list of items provided by Army is:

(1) Tyvek overalls.
(2) Green PVC gloves. Protector Safety.

(3) Assorted rags.
(4) Yellow air line. 4720.66.027.6102.
(5) Mask. Protector Safety RFF 90.
(6) Belt & hose attached to the mask.
(7) Length of rope with a hook on one end (for rescue purposes).
(8) Small rope with cuffs on either end.
(9) Harness. Protector Safety. Cat no. MSH 71.
(10) Metal bucket.
(11) Rubber Scraper.
(12) Torch.

4. Measurements

4.1 Measurements Conducted at RAAOC Albury

Measurements were conducted either (1) during a visit to RAAOC Bandiana, (2) under controlled humidity conditions in the laboratory or (3) on a TFC that was installed outdoors at AMRL.

The measurements at RAAOC were made on 21 October 1994. The humidity was 26 ± 5 % and the temperature was 22°C for the duration of these measurements.

4.1.1 Resistance of TFC

Resistance to earth measurements in Table 1 were carried out on the surface of the TFC. Measurements were made at 500 V d.c. using a dry square electrode of 25 mm side where necessary.

Table 1: Resistance to earth from selected TFC locations

Location	Resistance (ohm)
Metal frame of access hole	3×10^6 to 1×10^9
Lower interior surface	1×10^9 to 7×10^{11}
A seam on lower interior surface	6×10^9
Upper exterior surface	2×10^{10}

4.1.2 Footwear Resistance for AMRL Personnel

Resistance was measured between a hand-held metal electrode and a metal plate on which the person was standing. The potential used was 500 V d.c. unless stated otherwise.

Table 2: Body-to-ground resistance of various AMRL personnel

Subject	Resistance (ohm)
JQ	2×10^9
GB	2×10^7
HB	$< 1 \times 10^6$, 9×10^5 *

* The second reading was conducted using an applied voltage of 250 V d.c.

4.1.3 Peak Potential Measurements

Peak potential measurements were made on subjects walking or standing on the surface of a TFC. The potential was monitored while the subject carried out activities that typically induce a static charge. In test 1 standard street shoes were worn, while in test 2 the subject changed to antistatic shoes. In test 3 a soldier wearing Brown GP boots walked on the TFC. In test 4 the subject stood on the TFC surface while being rubbed with a styrofoam panel, a material that is effective at generating electrostatic charge. For each activity the electrostatic energy on the subject is calculated using a body to ground capacitance of 120 picofarad.

Table 3: Peak potential measurements

Test	Subject	Action	Potential (V)	Energy (μJ)
1	GB	Rubbing Shoes on TFC	10 to 20	0.006 to 0.024
2	GB (antistatic shoes)	Walking	< 10	<0.006
3	Soldier	Walking	< 10	<0.006
4	JQ	Subject rubbed with Styrofoam	200 to 300	2.4 to 5.4

4.1.4 Potential Decay Time

The dissipation effectiveness of footwear can be indicated by the rate at which charge accumulated on a person is dissipated to earth. In this measurement the subject is raised to a potential and then the time for the potential to decay to half the initial value is measured. In each case the decay time was measured as less than a second. This indicates that the footwear tested on all subjects have appropriate electrical characteristics.

The measurements in Table 4 were made for AMRL subject JQ and a soldier on or near the TFC. The soldier was wearing DPCU and Brown GP boots in addition to either Saranex or Tyvek overalls. The subject JQ was wearing civilian dress.

Table 4: Decay time measurements

Subject	Attire	Surface shoes in contact with	Initial Potential (V)	Half Time (s)
JQ	Civilian Clothes	Top of TFC	1000	< 1
Soldier	Saranex Overalls	Concrete	100	< 1
Soldier	Saranex Overalls	Concrete	50	< 1
Soldier	Tyvek Overalls	Concrete	50	< 1

4.1.5 Static Charge Accumulated from Simulated Rescue

In the event of a person inside the TFC becoming incapacitated, attendants outside the TFC drag the person to the access hole and safety. This action could be an effective method of inducing electrostatic charge. Accordingly the potential and capacitance measurements (to earth) in Table 5 were conducted for a soldier dragged across the TFC surface while he was lying on his back. The soldier was dressed in DPCU, brown GP boots and either the Saranex or Tyvek overalls. For some measurements the soldier wore a harness.

Table 5: Measurements on soldier during simulated rescue

Overalls	Harness	Capacitance (pF)	Potential (V)	Energy (μJ)
Tyvek	Yes	NA*	50	NA
Saranex	Yes	NA	200, 50	NA
Tyvek	No	1000	25 to 40	0.3 to 0.8
Saranex	No	1600	0 to 20	0 to 0.3

* Quantity not measured.

4.2 Laboratory Measurements

4.2.1 Laboratory Testing of Electrostatic Charging while Wearing Brown GP Boots

The electrostatic charging of a variety of garments was measured immediately after the wearer brushed against aluminium and painted metal surfaces while wearing Brown GP Boots. This situation could occur, for example, when an operator brushes against a vehicle situated near the TFC with an explosive atmosphere outside. In the tests (Table 6) an operator wearing one of the garments and a pair of Army Brown GP Boots brushed his back against either an aluminium or painted metal sheet. After brushing he moved away from the metal surface and, while standing on an earthed metal plate, took one step. The peak body potential during this action was monitored. The peak potential occurred during a part of the step with one foot off the ground.

The electrostatic energy on the body was calculated after measurement of the body capacitance to ground. The body to ground capacitance while wearing (Highmark) Brown GP Boots was 140 pF with two feet on the ground and 105 pF with one foot on the ground. All the materials used in this test were conditioned and tested at 25°C and 20 % relative humidity.

Table 6: Charging tests for an operator wearing GP boots

Test No.	Garment	Brushing Surface	Potential (V)	Energy (μJ)
1	Tyvek	Aluminium Painted metal	-500 -100	13 0.5
2	Saranex	Aluminium Painted metal	-1000 -200	52 2
3	Linstat Breathalon	Aluminium Painted metal	-100 -1000	0.5 52
4	DPCU	Aluminium Painted metal	-100 +150	0.5 1.2
5	DP Cantas jacket	Aluminium Painted metal	+1000 +1000	52 52
6	Khaki sweater	Aluminium Painted metal	-100 +150	0.5 1.2

4.2.2 Laboratory Testing of Electrostatic Charging while Wearing Insulating Footwear

The electrostatic charging of a variety of garments was measured immediately after the wearer brushed against aluminium and painted metal surfaces while wearing insulating footwear. The tests in Table 7 were identical to that carried out with the brown GP boots except that the footwear worn were sports shoes (Puma) which are highly insulating. The peak potential was recorded after one step with both feet on the ground. The capacitance was 102 pF and this value was used for the energy calculations.

4.3 Experiments Conducted on the TFC at AMRL

4.3.1 TFC Setup

The TFC at AMRL was laid out in a deflated state on a concrete surface and a corner of the TFC was raised to form a vertical surface. The setup (Fig. 3) was such that an operator could rub against the vertical rubber surface and then step onto a horizontal surface of the deflated TFC. This setup adequately simulates the activities of an operator inside the TFC during cleaning operations.

Table 7: Charging tests for an operator wearing sports shoes

Test No.	Garment	Brushing Surface	Potential (V)	Energy (μJ)
1	Tyvek	Aluminium Painted metal	-100 -800	0.5 33
2	Saranex	Aluminium Painted metal	-3000 -3000	460 460
3	Linstat Breathalon	Aluminium Painted metal	+100 +2000	0.5 204
4	DPCU	Aluminium Painted metal	-200 -600 to +300	2 18
5	DP Cantas jacket	Aluminium Painted metal	+200 to +500 +3000 to +4000	13 816
6	Khaki sweater	Aluminium Painted metal	-100 +300	0.5 4.6

4.3.2 Charging of Operator on TFC While Wearing GP Boots

For the results in Table 8 the subject wore the DPCU uniform, GP boots and the typical gear for entering the TFC. The operator rubbed his back against the vertical rubber surface, separated and then stepped onto the rubber surface of the tank, then his potential was monitored. The humidity for these tests was 30-35 %. The samples had been conditioned at this humidity for an hour before testing. Prior to this the samples had been kept at 20 % humidity for more than 24 hours. The operator's body to ground capacitance was measured as 106 pF. Adding a harness or holding a bucket did not increase the accumulated energy on the operator.

Table 8: Charging for an operator rubbing against the TFC surface. Operator wearing GP boots

Overalls	Peak Potential (kV)	Peak Energy (μJ)	Half Time (s)
Saranex	-0.270 to -0.390	3.9 to 8.1	0.3 to 0.5
Breathalon	0.840 to 1.310	37 to 91	0.3

4.3.3 Charging of an Operator Wearing Insulating Footwear

The operator exchanged the GP Boots for insulating sports shoes while otherwise wearing DPCU shirt and trousers with Saranex protective suit and typical gear for entering the TFC. In this case the harness was also worn. The charging process of rubbing the back against the TFC was carried out as for the previous section.

The samples were removed from a room where they had been kept at 20 % humidity for more than 24 hours and immediately tested outdoors at a relative humidity of 30 %. The body to ground capacitance and peak potential of the operator were measured as 82 pF and 2.3 kV, respectively. The peak energy was calculated as 217 μJ. The time for the potential to decay to half peak value was greater than 12 s. Holding a bucket produces equivalent or less electrostatic energy.

4.3.4 Charging of an Operator while Stepping onto Rag Samples

The operator wore the same gear as was used in 4.3.2 and carried out the same activities but stepped onto rag samples that had been placed on the TFC. The garments, footwear and rag samples had been conditioned at a humidity of 20 % for more than 24 hours and then immediately taken outside and tested. The rag samples were kept outside in a sealed plastic bag until required for testing. The humidity was 35 % during testing.

The peak potential on the operator was 2.5 kV and the capacitance was 80 pF. The peak energy on the operator was 250 μJ. The peak potential took less than a second to decay to half its peak value.

5. Electrostatic Safety Implications

With brown GP Boots and the garment and surfaces selected in this test, the energies measured on the operator (while stepping on an earthed, conducting surface) do not exceed the minimum ignition energy (MIE) of 250 μJ for hydrocarbon fuels [5]. With highly insulating sports shoes the minimum ignition energy can be exceeded by a factor of two if Saranex overalls are worn.

In none of the tests conducted on the TFC at AMRL was the MIE for hydrocarbon fuels exceeded when brown GP boots were worn. Breathalon overalls produced higher peak potentials than the Saranex overalls under the same charging conditions. The time for the peak potential to decay to half value never exceeded 0.6 s provided brown GP boots were worn and the operator stepped directly onto the TFC surface. Similar low decay times will also occur if the operator steps onto concrete or soil [10]. It had previously been determined [6] that GP boots exhibit good charge dissipation properties.

Various maximum allowed decay times have been postulated [11]. However, if the decay time exceeds about a second then this clearly constitutes a hazard since sufficient time may exist for the charged person (or object) to discharge the accumulated energy in the form of a spark before dissipation has reduced the charge to a safe level. The results in section 4.3.3 show that the decay time can become unacceptably long if insulating footwear is worn in place of the GP boots.

The results in section 4.3.4 indicate that peak energies approximating the MIE for hydrocarbon fuels are possible if the operator steps on rags under low humidity conditions.

6. General Safety Implications

6.1 Breathing Apparatus

The cleaning operations for the TFC pose a number of occupational health and safety issues beyond that of electrostatic discharge ignition of fuel vapours. Suitable air quality cannot be assured over the entire volume of the TFC even with the high volume blower that is used to inflate it. Breathing apparatus via an airline is mandatory since parts of the volume inside the TFC have low oxygen (< 18 %) content. This fact is already reflected in the regulations for cleaning operations.

6.2 Suit Encapsulation Implications

The nature of the fuels, which might contain additives such as de-icing agents and possibly benzene, requires that skin contact be avoided. Saranex and Breathalon suits are reputed to provide an effective barrier against fuels, but they also encapsulate the wearer. The Breathalon suit has a limited ability to transpire moisture from the wearer to the outside of the suit.

Encapsulation seriously impairs the capacity of the wearer to eliminate waste heat. The cooling effect normally achieved by evaporation of body fluids is almost completely negated, giving rise to the possibility of core body temperature rising. The effect is particularly critical in the warm to hot weather conditions that predominate in the operational areas of the Australian Army. Studies of the physiological effects of working while wearing encapsulating suits under warm conditions point to a number of hazards which need to be addressed for the safety of personnel [7].

6.3 Minimum Dimensions of the Access Hole

Entry and egress of the TFC for personnel is sufficiently difficult that assistance is required. Exiting the TFC could only be achieved by placing both arms out through the access hole before attempting to remove the rest of the body. The maximum dimension was measured as 400 mm which is obviously inadequate. Australian Industrial standards for entry access to a confined space [8] requires a minimum of 450 mm.

6.4 Flame Resistance Suitability

Neither the Tyvek nor Saranex garments are flame resistant and, according to a manufacturer's report [4], they should not be used in potentially flammable or explosive environments.

6.5 Overseas Practice

It has been brought to our notice [9] that personnel in the armed forces of the US and the UK are not required to enter similar fuel tanks for cleaning purposes.

7. Conclusions

1. If appropriate footwear is worn and the shoe soles make contact with the TFC surface (to provide a dissipation path for charge) the electrostatic energy on a person wearing Saranex or Breathalon protective suits will not exceed the minimum ignition energy of fuel and the accumulated potential dissipates rapidly.

2. If inappropriate footwear is worn, then under some circumstances the electrostatic energy on a person wearing Saranex or Breathalon can accumulate to a level that exceeds the minimum ignition energy for fuel. In addition, the energy on a person takes an unacceptably long time to dissipate.

3. Under the same charging conditions for an operator rubbing against the TFC the Breathalon protective suit generates higher peak energies than the Saranex suit.

4. The material which forms the 45,000 liter TFC has adequate charge dissipation qualities.

5. Encapsulation of personnel in fuel-impervious protective suits presents a health hazard to the wearer in hot climatic conditions [7].

6. The access hole for the 45,000 L TFC does not comply with Australian Standard AS 2865-1986.

7. It must be ensured that the operator does not interrupt the discharge path to earth by standing on any insulating objects placed on the floor of the TFC (e.g. cleaning rags). In our case the hazard presented is assessed as marginal because the peak energy on the operator in 4.3.4 was found to be 250 μJ which is exactly the MIE value for a hydrocarbon-air mixture.

8. The Tyvek and Saranex garments are not flame resistant.

8. Recommendations

The authors draw the attention of the Army sponsor to conclusions 2, 5, 6 and 7 above and strongly suggest that they be addressed. In particular, the benefits of cleaning the TFCs must be weighed against occupational health and safety considerations. We note that US and UK practice does not require personnel to enter similar fuel tanks for cleaning purposes.

9. Acknowledgments

The collaboration of Captain D.M. McKeon and WO1 B. Currell in the conduct of experiments and in the provision of information is appreciated. B. Gray and G. Egglestone, both from AMRL, are also acknowledged for useful discussions on the properties of protective clothing and the physiological effects of working in warm climates.

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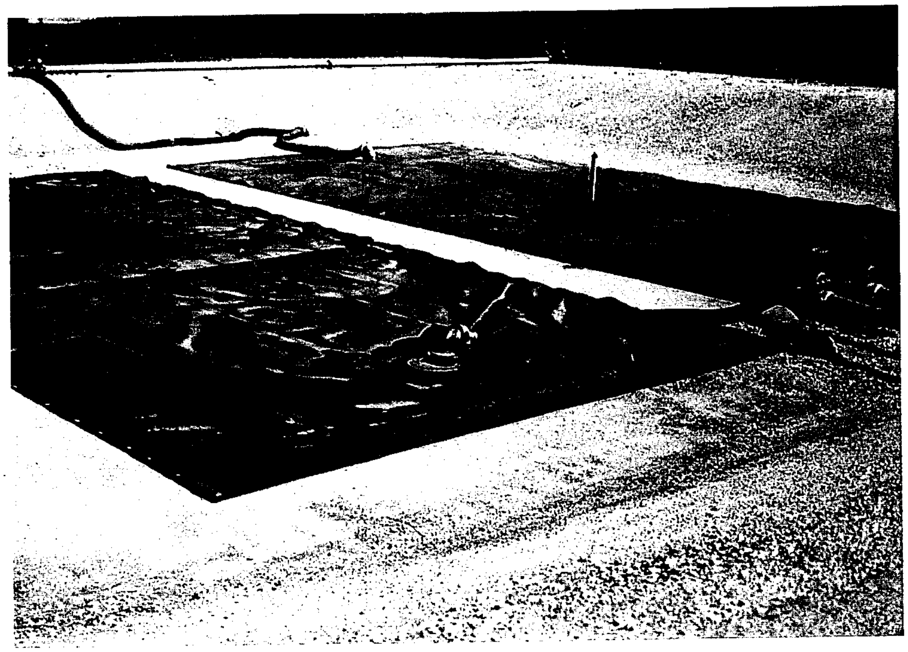

Figure 1: A TFC laid out in a bund.

Figure 2: A simulated rescue operation from a TFC.

Figure 3: An operator wearing TFC entry attire.

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DOCUMENT CONTROL DATA

1. PAGE CLASSIFICATION
UNCLASSIFIED

2. PRIVACY MARKING/CAVEAT (OF DOCUMENT)

3. TITLE

Electrostatic and general hazards associated with cleaning Army fabric bulk fuel tanks (TFCs)

4. SECURITY CLASSIFICATION (FOR UNCLASSIFIED REPORTS THAT ARE LIMITED RELEASE USE (L) NEXT TO DOCUMENT CLASSIFICATION)

Document	(U)
Title	(U)
Abstract	(U)

5. AUTHOR(S)

Gunars Bajinskis, Horace Billon and Jim Quinn

6. CORPORATE AUTHOR

Aeronautical and Maritime Research Laboratory
PO Box 4331
Melbourne Vic 3001

7a. DSTO NUMBER	7b. AR NUMBER	7c. TYPE OF REPORT	8. DOCUMENT DATE
DSTO-TR-0254	AR-009-401	Technical Report	November 1995

9. FILE NUMBER	10. TASK NUMBER	11. TASK SPONSOR	12. NO. OF PAGES	13. NO. OF REFERENCES
510/207/0432	ARM 94/355	SOC-LC	25	14

14. DOWNGRADING/DELIMITING INSTRUCTIONS

To be reviewed three years after date of publication

15. RELEASE AUTHORITY

Chief, Weapons Systems Division

16. SECONDARY RELEASE STATEMENT OF THIS DOCUMENT

Approved for public release

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17. DELIBERATE ANNOUNCEMENT

Announcement of this report is unlimited

18. CASUAL ANNOUNCEMENT YES/NO (Cross out whichever is not applicable)

19. DEFTEST DESCRIPTORS

Electrostatics; Occupational health and safety; Fuel tanks; Protective clothing; Fuel hazards; Hazardous materials; Static charges

20. ABSTRACT

Assistance has been sought to assess the safety from electrostatic hazards of personnel cleaning the 45,000 L tank fabric collapsible (TFC) that is used by the Australian Army for fuel storage. Concerns centre on the level of electrostatic charge that may be generated on personnel while wearing protective suits and working inside the TFCs. If inappropriate attire is worn the energy of an electrostatic discharge from personnel can exceed the ignition energy of the most sensitive concentration fuel air mixture. Electrostatic tests were carried out on suits supplied and several conclusions regarding safe working conditions are listed. Although not directly related to electrostatics, other occupational health and safety aspects are raised in the report.